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Articles PAGE

Robert Alexander Gray, 1861-1935 (with Plate VI) *J. H. Horning* 33
The Application of the Spectroscope to Astronomy *Frank S. Hogg* 35
The White Dwarf A.C.+70°8247, the Smallest Star Known - - - - - - - - *G. P. Kniper* 48
Radio Talks over CFCT, Victoria, B.C.,: 79 Planetary Atmospheres; 80, The Atmosphere of the Earth - *W. E. Harper* 49
The Green Line of the Aurora - - - *J. F. Head* 55

Meteor News

The Carolina Bays and their Supposed Meteoric Origin—Meteor Photography in Texas—Nebulous Meteors - *P. M. M.* 57

Notes and Queries

Prophets of Science—Royalty and the Time—The Late R. A. Gray - - - - - - - - - *C. A. C.* 61

Meetings of the Society

At Vancouver—At Victoria - - - - - - 63

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PLATE VI

ROBERT ALEXANDER GRAY, 1861-1935

Lately General Secretary and Librarian of the Royal Astronomical Society of Canada

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ROBERT ALEXANDER GRAY

By J. H. HORNING

(With Plate VI)

WITH the passing of R. A. Gray, B.A., the Royal Astronomical Society of Canada has lost one of its most outstanding and valued members. His death on December 24, 1935, at the age of 74, has deprived the Society of a faithful worker and his associates of a tried and trusted friend.

Mr. Gray's birthplace was Largs, Scotland, a town on the Clyde not far from Glasgow. His father, Robert Gray, was a Presbyterian minister, who moved to Canada about the year 1871 when young Robert was only ten years old. The family lived for many years near Hogg's Hollow on Yonge St., now at the northern boundary of Toronto. Here the boy received his primary education, but to attend secondary school he had to walk the long journey (over five miles) to the Jarvis St. Collegiate Institute, Toronto. He then went to the University of Toronto where he had a brilliant record for scholarship, graduating in 1884 as Silver Medallist in Physics.

His chosen profession was that of schoolmaster. He taught at Orangeville and London and then in 1900 returned to be the head of the department of mathematics at the Jarvis St. Institute. In 1909 he was made principal of Malvern C.I. and one year later was appointed head of the new Oakwood C.I., Toronto. Under his control this school of 200 pupils grew to a large Institute of 1,200 pupils and 40 teachers. After 21 years in this high position he retired in 1931 on reaching the age of seventy. Under him the

school had achieved distinction among the secondary schools of the province, second to none both in scholarship and in clean sports.

His great ability was further proved by the other responsible posts he filled. As an actuarial expert he represented the teachers on the Provincial Superannuation Board from its organization. All teachers owe him a debt of gratitude for the efficient management of their funds and for his support in demanding just treatment for any teacher's case under consideration. During his career he was president of the Ontario Educational Association, also adviser in the publication of text books, and for many years he was a member of the Senate of the University of Toronto.

For hobbies he chose painting, mountain climbing and astronomy. His sketches of landscapes, especially of Muskoka autumn scenes, compare favourably with those of professional artists. His interest in mountain climbing took him to the Rocky Mountains of Canada, the mountains in Wales and the Alps in Europe.

As an amateur astronomer his interest grew with his years. Since his retirement he has rendered valuable service to the Royal Astronomical Society of Canada. He was chairman of the Toronto Centre during the years 1931-34 and performed his duties efficiently and conscientiously. In 1932 he sketched the eclipse of the sun at Louiseville, Quebec. From 1932 until his death he was General Secretary and Librarian of the Society.

Those who have known Mr. Gray well, will long miss his support and friendship. He was a wise counsellor, a defender of righteousness, a warrior against any evil, a doer of charitable acts, a kindly man and a Christian gentleman. His unspoken motto was "To follow duty to the end". His other outstanding traits were, sympathy, fairness, strict honesty and a great love for small children. Mr. Gray was never married.

THE APPLICATION OF THE SPECTROSCOPE TO ASTRONOMY*

By FRANK S. HOGG

THE spectroscope is applied to astronomy to furnish the observational basis for two broad fields of research, the determination of the motions of astronomical bodies, and the study of their physical and chemical constitution. Professor Young has dealt with the methods of deducing the line-of-sight motions, or radial velocities of the stars. We shall here outline how, from the distribution of energy along the spectrum, from the presence of lines of various elements, and from the strength and shapes of these lines, our knowledge of the stars themselves has been derived. Recent striking advances in the study of the spectra of other objects, such as the nebulae, planets, and meteors, are not included.

The Observational Material

For a quantitative study, the observational material ideally would consist of a knowledge of the absolute intensity of the spectrum, at every wave length, both in the continuous spectrum and across the absorption lines. The dispersion and resolution, of course, should be so great that the instrumental line widths would be so small as to be negligible compared with the widths of the true stellar lines. In the physical laboratory and in the study of the sun, by means of gratings and interferometers, such a condition may be fairly approximated; in the study of the stars the total light is so small that even the largest reflectors, working on the brightest stars, do not collect enough light to allow spectra comparable to that of the sun to be obtained in practicable exposure times. We must then bear in mind that our deductions in astrophysics rest on material in which the resolution is too small to allow highly accurate quantitative results for the shapes or "profiles" of lines and that the great wealth of lines in most stars makes it difficult to secure lines unaffected by blending with one another.

*An illustrated lecture at the University of Toronto, December 20, 1935.

The actual measurement of the intensity is usually carried out photographically, by methods such as are used in many physical laboratories. The general principle is to have impressed on the same plate as the star spectrum a series of carefully graded spectra from standard sources. The latter may be an electric bulb which is burned at constant voltage and current, to give a definite known energy distribution. The intensity differences between successive graded steps are known. By means of an auxiliary measuring machine or microphotometer, the blacknesses of the images of the spectra are measured at each wave-length, and by interpolation, the energy of the initial starlight, at that wave-length, found in terms of the standard lamp. In this way the energy distribution in the star's continuous spectrum and the profiles of the individual lines may be determined quantitatively.

While for a detailed study of stellar spectra it is necessary to use the conventional form of spectrograph with a slit and collimating lens, yet for some purposes it has been found that much information may be obtained from a modified form of spectrograph, known as the "objective prism camera". In this instrument the collimating lens and slit of the standard spectrograph are eliminated. The starlight is allowed to fall directly in the prism and is brought to a focus by the camera lens. Such a process is permissible in that the stars are so far away that the wave fronts of their light are sensibly plane; in other words, the light is already collimated. The result is that each star included in the field of the camera lens forms its own spectrum, in the same relative position on the plate as if no prism were present. The great merits of this instrument are that the losses of light at the slit are eliminated, that a large number of stars may be photographed at one exposure, and that the energy distribution in the spectrum is unaffected by chromatic guiding errors at the slit. Its definition is, of course, limited by the unsteadiness of our own atmosphere.

The Draper Classification

With such objective prism cameras, several hundred thousand spectra have been obtained for statistical studies. This ample material shows that over ninety-nine per cent. of the stars studied have spectra which may be divided into one of seven main classes

depending on their absorption spectra, designated O, B, A, F, G, K and M, while with very few exceptions the remaining stars may be classed as R, N, or S. A striking feature of this spectral series is that it is continuous, the various classes blending into one another. In practice the main classes are subdivided into decimal divisions, which in turn blend to form a continuity throughout. The criteria for classification vary somewhat with the instrument used, but the general features are very definite. A given line may be most prominent in a certain class, but often appears in classes on either side. The O type stars are characterized by lines of ionised atoms of high ionisation potential, including such elements as ionised helium and doubly and trebly ionised oxygen and nitrogen. In the earlier B stars these highly ionised atoms give way to neutral helium and singly ionised nitrogen and oxygen. In the A stars the Balmer series of hydrogen reaches a maximum, and a vast number of lines of the easily ionised metals appear. In the F stars, these ionised metals predominate, but lines of neutral metals appear. In class G these neutral lines become stronger than the ionised lines, and through the K and M stars the neutral metallic lines become increasingly prominent. In the M stars, as also in the R, N, and S stars, molecular band spectra become conspicuous. The M stars show strong bands of titanium oxide, the R and N stars bands of carbon and cyanogen, and the S stars those of zirconium oxide. The Balmer series of hydrogen is unique in its presence throughout the sequence; the stellar lines of ionised calcium are next most prevalent, appearing in all the classes from later B through to M.

From the identification of the lines in the stars we secure our qualitative knowledge of their composition. Even in the sun, where large scale photographs show over twenty thousand lines, the great majority, including all the strongest lines, are identifiable as arising from known terrestrial atoms. In the stars, as is seen from the Draper classification, the prominent lines are all due to elements known on the earth. Yet the spectra of different classes differ so radically that it was early supposed that differences in chemical composition actually existed. With increasing knowledge of atomic physics it became clear that the major differences were due to the degree of excitation and hence to differences in temperatures of the stars.

Early measures of the colours of stars had shown that the colour was definitely, and almost linearly, related to the spectral class. The O stars appeared bluest, and succeeding classes were progressively redder till the M and N stars were reached. To interpret these colour differences on a temperature scale, spectrophotometric observations must be used. If stars radiate as black bodies, according to the well known relation between energy E_λ, wave-length λ, and absolute temperature T,

$$E_\lambda = \frac{c_1 \lambda^{-5}}{e^{c_2/\lambda T} - 1}$$

the measured energy distributions may be fitted to this formula and the temperature deduced. The difficulties of the procedure are very great. In the first place, the observations must be made from the bottom of the terrestrial atmosphere, and hence need to be corrected for atmospheric absorption, which is not achromatic nor constant from time to time. The differential refraction of the atmosphere causes a chromatic guiding error at the slit of the spectrograph. To obtain a good intensity distribution the slit should be opened widely enough to include the whole image, which greatly decreases the resolving power of the spectrograph. This is especially serious in the case of the cooler stars, where the spectrum is so rich in metallic lines that it is difficult to find regions of continuous spectrum to study. Even if the observations are accurately made, we can examine only a limited region of wave-length, from about 3000A to 7500A. For the hotter stars the differences with temperature in this range become small. In determining temperatures from the Planckian law, it must be borne in mind that the radiation from a star is obviously, even in the observable region, not truly black body. Yet these departures from black body radiations may to a first approximation be allowed for, and so radiation temperatures derived. By such means a temperature scale is set up for the spectral sequence, extending from over 40,000° K for the O stars, to 12,000° for A, to 3000° for the early M stars, and considerably lower for the later M's and N's. Such a range in temperature accounts qualitatively for the chief characteristics exhibited by the line spectra of the various classes.

Ionisation Theory

If we attribute the differences between spectral classes to temperature alone, we encounter a serious difficulty when we examine in detail the atmosphere of the sun. At the time of solar eclipses, due to the interposition of the moon, we are able to secure spectra of different levels in the atmosphere of the sun, at its limb. It is then found that the outer layers of the sun exhibit lines usually associated with earlier types of stars than the sun as a whole. As the source of the heating of the atmosphere is the radiation from the central regions of the sun, it is unreasonable to suppose that the outer layers of the atmosphere can be at higher temperature than the lower layers, and so the spectrum must depend on some other strong physical factor. This consideration led Saha to the recognition of the role played by pressure in stellar atmospheres. Following Eggert, he treated the atmosphere of the sun as an equilibrium system of physical chemistry, and applied the dissociation laws. Instead of considering the dissociation of chemical compounds into their constituent atoms, he considered the termal ionisation of atoms into ions and electrons. Ionisation potential thus replaced heat of dissociation, and the fraction of any particular kind of atoms ionised could be found in terms of temperature and pressure. In its simple form, Saha's equation may be written

$$\log \frac{x}{1-x} = -5048I + \frac{5}{2} \log T - 6.5 \log P_e$$

where x is the fraction of atoms of ionisation potential I, ionised at a temperature T, and a surrounding partial pressure P_e of the electrons. For the sun, Saha assumed the temperature as being known and constant throughout the atmosphere. By following any given neutral lines through successive layers of the solar atmosphere till it gets so high as to disappear, the pressure could then be obtained as a function of depth in the atmosphere. Similarly, the Draper classification may be examined on the basis of this theory, whence it is found that, as had been supposed, temperature is the primary defining condition for the classification. The above theory predicts quantitatively how, at lowest temperatures all the atoms will be neutral; as the temperature rises, the number of neutral atoms remains almost constant until a critical point is reached,

where appreciable ionisation commences. The neutral atoms then decrease rapidly; and singly ionised atoms appear. With increasing temperature the ionised atoms reach a maximum. Then, depending on the value of the potential for the next ionisation, the number of singly ionised atoms decreases, and those doubly ionised appear. Qualitatively this describes the Draper classification very well. The pressures indicated are of the order of 10^{-5} atmospheres.

This theory of thermal ionisation has, of course, to be greatly refined to apply it accurately to the stars. The atmospheres of the stars are not single layers in equilibrium but ill-defined regions in which the temperatures and pressures are a maximum at the bottom and fade off towards zero as we proceed outwards. Nor is the bottom at a definite location in the star, but varies with the wavelength, depending on the opacity and hence the depth to which we see. A further point is that the temperature used is not merely the temperature associated with the thermal agitation of the atoms, but more nearly the temperature associated with the radiation streaming out through the atmosphere. The necessary amplifications of the theory have been propounded by various authors.

Even if we form a satisfactory model of the physical structure of the star's atmosphere, we must still bear in mind that we do not directly observe this fractional ionisation. The quantity observed is the strength, or in case of stronger lines, the profile, of the lines; and this is observable over only the small range of spectrum in the visual and photographic regions. The relation between the number of atoms of any kind present in the atmosphere and the strength of the line produced, is rather involved. Idealised, we should like to know (*a*) the fraction of the atmosphere made up of the element concerned, i.e., the relative abundance of the element; (*b*) the fraction of these in the state of ionisation to which the given line belongs; (*c*) the fraction of these in the correct initial stage of excitation; (*d*) the transition probability for the line concerned; and (*e*) the number of active atoms required to produce a line of given characteristics. If we can determine the latter three of these quantities, we can then find the degree of ionisation, and derive the abundance of the various elements and the ionisation conditions.

There are two main lines of attack on the problem of the relation between the number of active atoms and the strength of the lines

produced. The first of these is an application of Schuster's early work on the widening of lines by scattering. This work showed that the width of absorption lines should be proportional to the square root of the number of atoms producing the line. It is possible to compute the exact scattering profile of the line, and, for the stronger lines, compare the observed and computed curves. Here again the simple theory needs adjustment, which has been made to a certain extent. The result is the discovery that even the most striking lines in the spectra of stars are produced by as few as 10^{19} atoms per square centimeter of the star's surface.

The second method, as developed by Russell and Adams, is a direct calibration of the line intensities in stellar spectra as a function of number of transitions. It is based on the hypothesis that the relative number of transitions in each line of any multiplet is given by the theoretical transition probabilities. In this way, by combining many multiplets, a scale over the complete range in intensity is built up, giving, for any star, a relation between observed intensity and the number of atoms acting to produce the line. In either method, the total number of atoms making the transitions which produce the lines in the observable region may be added together and allowance made, from a knowledge of the energy states of the atom, for the transitions in the inaccessible region of the spectrum. In this way, the total number of atoms in the particular state of ionisation may be found.

One of the most interesting results of a quantitative analysis of stellar spectra is the determination of the relative abundance of the various elements. For a few elements in which all the strong lines of the state of ionisation corresponding to the temperature of the given stars lie in an inaccessible region, quantitative or in some cases even qualitative evidence as to the abundance is lacking. In general, however, enough lines are available to give a fair determination. Miss Payne early showed that the stars were very similar in chemical compositions, and that there was even a general quantitative correspondence between the chemical make-up of stars of the earth. More recently Russell has obtained very complete information on the composition of the sun. By weight, hydrogen with 46%, oxygen 24%, and helium 6%, are the most abundant elements; in general the lighter elements are the more plentiful;

and those atoms of even atonomic number greatly exceed those of odd atomic number. The metals total 24%, composed mostly of magnesium, iron, silicon, sodium, potassium and calcium. Except for the great abundance of hydrogen—part of which is due to difficulties in interpretation—the composition is thus very similar to that of samples of the earth.

While in general the linearity of the spectral sequence indicates an interesting uniformity of chemical composition in the stars, yet there are a few indications of objects which show divergences from the mean. The most striking case is that of the cool stars, the M and N classes. In these the temperatures are of the same order; and the underlying atomic spectral lines correspond fairly well. Yet the characteristic features—the bands of titanium oxide in the M stars, and of carbon and cyanogen in the N's, seem to be mutally exclusive; as a result the spectra are very dissimilar. This difference may be quantitatively explained by rather small differences in chemical composition. If instead of applying a chemical dissociation formula to ionisation processes, we use it as originally, as a molecular dissociation formula, the partial pressures of compounds such as TiO, CN, C_2, may be found on the basis of varying abundances of the constituent atoms. If the normal abundances (oxygen more plentiful than carbon) are taken, it is found that the bands of TiO predominate. If the abundances of carbon and oxygen are reversed, there is enough carbon present to hold most of the oxygen as CO, and leave an undetectable amount free to combine to form TiO. Thus, depending on the relative abundance, we have "oxygen", or M stars, and "carbon" or N stars.

This type of difference has also been found in some of the hottest stars, in the numerically small class designated as Wolf Rayet. Here Beals has found that there are two distinct, and evidently mutually exclusive types, characterized by abundant nitrogen and carbon. In other classes there are some stars showing one or more elements somewhat more abundant than on the average; and we conclude that, while the uniformity of chemical composition is marked in stellar sources, there are some rather small differences which may be of great significance.

Once the total number of atoms in different states of ionisation can be determined, and compared for different elements, the ionisa-

tion equation gives much more definite information on temperature and pressure. In this way, the pressure of the atmosphere of the sun is found to be about 2×10^{-5} atmospheres. Other stellar atmospheres give similar low pressures.

In the foregoing the spectral sequence has been regarded as purely linear. In actual example however, it was found twenty years ago that there were very minor differences between stars of the same subclass. Adams and Kohlschutter found that these differences were correlated with the absolute brightness of the stars; and, since the apparent brightnesses were measurable, a powerful empirical method, that of *spectroscopic absolute magnitudes*, was thus developed for deducing the distances of the stars, since the apparent brightness falls off inversely as the square of the distance. If we consider stars of the same temperature, but different absolute brightness, this latter factor must indicate that the stars are of different size, since by the radition laws the energy per unit area is equal. From other data it is known that this difference in size is much greater than the difference in masses of the stars—so that we are forced to conclude that the surface gravity, and hence pressure, is greater for small faint stars than for corresponding large bright ones.

On the simple Saha theory the differences were then explained as due to differences in pressure. It is obvious that there can be partial compensation in temperature for differences in pressure, so that the spectra for all lines of average excitation will be about the same regardless of pressure. For lines of other excitations, there will be a dependence on pressure, that is, on absolute brightness. The early comparisons of the empirical and theoretical results were rather disappointing. More recent work has shown that this was due to neglect of the varying opacity and optical depth in stars of different absolute magnitude. Detailed models remove many of the discordances.

Widening of Spectral Lines

We have in the above discussion assumed that the width of the line depended only on the number of atoms acting to produce the line. In actual stellar spectra, however, we are led to conclude that there are several other important factors which change the

line profile. It is frequently difficult to disentangle the various effects, but there is much valuable information to be derived from the study of the various possible causes of widening.

Rotation seems to be a fairly common feature of celestial objects. In the case of one star, our own sun, we can definitely measure the rotation. In the case of other stars where the distances are so great that the spectra of opposite limbs cannot be compared for Doppler shift, any spectroscopic evidence must be gathered from the whole disc. In the case where the axis of rotation is perpendicular to the line of sight, the region along the central meridian of the star's disc will have no component of radial velocity. Proceeding from this meridian towards the edge of the disc there will be increasing velocity of approach on one side, and of recession on the other, with maximum velocity components corresponding to the opposite limbs at the equator. Thus, if the line were originally truly monochromatic, its form by rotation would become shallower and wider with a profile a semi-ellipse, of a width corresponding to the maximum equatorial velocity. In actual cases, as we have seen above, the line is not originally monochromatic, but has a width due to the abundance of the absorbing atom. The rotation effect then acts to symmetrically widen each elemental width of the original line, and the observed line is the integration of the Doppler widenings over the undisturbed profile.

A good test of this effect is found in some of the spectroscopic binaries of smallest separation, such as were described in the previous paper. In many cases it appears that the component stars keep the same face toward one another, that is, they revolve on their axes in their period of revolution. In certain cases, the plane of the rotation is known, as well as the period, and the radii of the stars. Thus the radial velocity can be computed, and compared with the observed widening. Two features of such rotational broadening are that its superposed elliptical profile must be independent of the element selected, and vary directly with the wavelength of the line considered. The effect observed corresponds closely with that predicted.

It is then natural to proceed, from these cases of known rotation to a study of the spectra of single stars. It is found that the rotational broadening is marked for many of the hottest stars.

Depending on the orientation of the axis in space, and the rotational period of the star, the widening varies from zero to over two hundred km/sec. The spectra of the cooler stars apparently are little affected by rotation. In the case of the sun, a faint G star, the measured rotational velocity is only two km/sec, a quantity too small to produce a detectable change in the spectrum of the sun were it so distant we had to analyze the light of the disc as a whole.

The Stark effect is probably another source of widening in certain lines of some elements. This effect is produced when atoms radiate in a strong electrical field. The latter produces a splitting up of the line into definite structure, which varies with field strength. In the case of stellar atmospheres, the field is furnished by the proximity of charged particles, the electrons and ionised atoms. At some times, just as a transition is taking place in an atom, an electron passes close to it, producing a certain Stark effect. The observed line in the star spectrum is made up by the combined action of large numbers of atoms. These will have, at any instant, electrons at a large range of distances, depending on the random space distribution of the electrons. The observed line will thus be made up of the integration of Stark effects of varying intensity, and the result is a general broadening of the line. Such broadening differs from the rotational effect in that its magnitude depends on the susceptibility of the particular energy state to being split up by the Stark effect, and hence differs greatly for different elements and for different lines of one element. The helium lines in stellar spectra which give the best observational evidence have been extensively investigated by Struve.

Expansion of the star's atmosphere would also produce a Doppler widening. As in the case of rotation, the widening should be proportional to the wave-length of the line. The superposed profile, however, will be markedly different. In this case, the maximum velocity of approach comes from the central region of the disc, and zero velocity from the limb. The whole line is thus bodily displaced to the violet, and it is readily shown that the profile is rectangular for a purely monochromatic line. Superposed on an ordinary stellar line, the result is a flat bottomed line, displaced to the violet.

In ordinary absorption line stars an obvious place to look for such effects is in the Cepheid variables, which are regarded as regularly alternately expanding and contracting. Here the pulsation theory was originally propounded to explain, among other anomalies, the periodic displacement of the lines. The determination of the expansion effect from the profiles themselves is more difficult.

Much more striking expansion effects are exhibited by the outer atmospheres of certain emission line stars, notably the novae at certain stages of their evolution, and the Wolf Rayet stars. These objects are characterised by wide flat-topped emission lines. These apparently are produced in a rapidly expanding envelope surrounding a hot star. A check on this interpretation is found in the case of certain of the novae, where the expansion has proceeded long enough, and the star is at a known, not too great distance, to allow the envelope to present an observable disc. Its measured extension may then be compared to that computed by integrating the observable velocities over the elapsed time. The source of these expansions is interesting, in that it evidently depends on radiation pressure. Thus while the widths of all lines of the same atom must obey the Doppler law, lines of different atoms, at the same wave-length, need not have the same velocity.

These emission line stars also are astrophysically important in that they are among the hottest stars known. The generally accepted theory of the source of the spectra is that ultraviolet radiation from the hot star ionises the atoms of the atmosphere, and the subsequent recombination produces an excited atom which in turn can give an emission line spectrum. The importance of this is that the strength of the emission lines is a measure of the ultraviolet radiation of the star. In this way the Planckian energy temperature may be derived over a long range of wave-length inaccessible in ordinary stars. This gives much more confidence to determinations of temperature for the high temperature stars.

Turbulence is a special case of expansion. Instead of the total expansion, it includes the case where there are large irregular mass movements in the atmosphere. Many stars show evidence of such motions in their spectra. The velocities indicated are rather small, from one or two to a hundred km/sec. In this case it is usual to

suppose the distribution of motions of the turbulence is more or less random, and will be the same for all elements, since the motions are of large masses of the atmosphere. Evidently the atmospheres of the stars must be regarded as being in a state of violent turbulence, rather than as quiescent equilibrium masses.

In regard to motions in the atmosphere, reference might be made to the motions observable in the atmosphere of the sun. By means of a spectroheliograph, a study may be made of the disc of the sun in light of any particular wave-length. The mechanism consists of a spectrograph which isolates the line desired, which is then made to "scan" the whole disc of the sun. In this way, the solar surface may be examined for irregularities and motions. Here it is found that while mass motions are not very rapid, there are rapid motions in the prominences and in regions of sunspots. These observations warn us against regarding our star, at least, as being in a too quiescent state.

To summarise, the spectroscope gives us most of our information as to the atmospheres of the stars. The stars are readily arranged, by their spectra, into an orderly sequence. The distribution of energy in the continuous spectrum establishes the temperature scale of this sequence. The identification of the stellar lines furnishes a qualitative analysis of the chemical composition. Estimates and measurements of the intensities of the lines, combined with the application of the theory of thermal ionisation give the pressures and permit quantitative deduction of chemical composition. More detailed studies of line profile serve to detect motions of rotation, expansion, or turbulence in the atmospheres of the stars.

THE WHITE DWARF A.C.+70° 8247, THE SMALLEST STAR KNOWN.

From a paper by G. P. KNIPER*

THE temperature adopted for this early-type star is 28,000°. It is taken from the values recently given by Trumpler and is based on the degree of ionisation in the atmosphere. The photographic magnitude has been determined to be 13.12, its colour index corresponding to temperature 28,000° is –0.38 mag., and hence the visual magnitude is 13.50. The parallax is uncertain, that given in Schlesinger's Catalogue of 1935 being 0″ 065, but all available evidence leads to the conclusion that this white dwarf is the smallest star known, its diameter being roughly half that of the earth.

"The average density, 36,000,000 (times that of water), is roughly a thousand times greater than that of Sirius B, which is about 40,000. Or, in more familiar terms, the amount of matter is on the average 620 tons per cubic inch, against somewhat less than one ton per cubic inch in the companion of Sirius.

"The density is so extreme that, had the star a companion moving in a circular orbit close to the surface, the period of revolution would be only two seconds. However, such a companion could exist only if it were itself a white dwarf of extreme density; otherwise tidal action would break it up.

"Of particular interest is the density gradient in the outer layers of the star. The surface gravity is 120,000 times that of the sun, or 3,400,000 times that on earth. The absolute temperature in the atmosphere of the white dwarf is about 100 times higher than on earth, and hence the density gradient is 34,000 times that of our own atmosphere. In our atmosphere the density increases to half its value at 5 km. elevation; for the outer layers of the white dwarf (neglecting the radiation pressure) the corresponding value is 15 cm. Hence, every foot the density (or the pressure) increases four times, every 5 feet, a thousand times, which is a billion times in the first 15 feet. The whole atmosphere of the star can hardly be more than a dozen feet deep."

*Publications of the A.S.P., Dec., 1935.

RADIO TALKS OVER CFCT, VICTORIA, B.C.

By W. E. Harper

No. 79.—PLANETARY ATMOSPHERES

(February 19, 1935)

Previous talks have dealt with the atmospheres of our earth, of Venus and of Mars. Oxygen and nitrogen, with traces of a few other gases, constitute our own rather extensive atmosphere. To some extent these elements are present also in Venus, whose atmosphere, however, consists largely of carbon dioxide. Mars has little or no atmosphere at all and likely the same is true of the other small planet Mercury, about which little is known.

The four major planets, Jupiter, Saturn, Uranus and Neptune, have extensive atmospheres as is attested not only by their low densities but by the oval-shaped appearance each presents. Jupiter and Saturn have been studied in detail and this flattening of the polar regions, due to rotation, extends with diminishing amount down to a considerable depth. Moreover, the rotation is not that of a solid body but different parts go round at different angular rates.

In keeping with the rapid axial rotation of these planets, particularly of Jupiter and Saturn, the atmosphere is drawn out into streaks or belts which are variously tinted. We learned in our last talk that since the surface temperatures are from one to two hundred degrees below zero centigrade, similar to that of liquid air, such cloud-like formations cannot be of the ordinary water vapour variety with which we on the earth are familiar. Some of these cloud-like belts are quite persistent and last for weeks or months and in some cases for years.

The question before us is as to the nature and composition of the atmosphere. We can well believe that when the planets were born the more massive ones could retain lighter gases which less massive ones would not be able to hold. Quantities of hydrogen and helium no doubt are important constituents of the atmospheres of Jupiter and Saturn, and it may be that the peculiar tints are caused in some way by reason of our having to view the lower and denser gaseous

material through these lighter gases. While such is only a suggestion we may well believe that the atmospheres of the major planets are richer in the lighter elements than is our own earth.

A suggested explanation is that the surface markings are due to the boiling of substances which "boil" at very low temperatures. If the temperature were as low as –183°C. oxygen would condense into a white cloud similar to our familiar clouds of fine water drops. At temperatures which were given in our last talk as likely for Jupiter (–100°) and Saturn (–150°) there are other substances, such as carbon dioxide, which would form clouds. As these formed and dissolved, owing to the circulation in the atmosphere, there would be presented to the observer such a changing panorama of detail as is actually witnessed.

All this is more or less speculation and we must turn to our spectroscope to learn definitely the composition of the atmospheres of these major planets. Their light when analysed shows, as was expected, that it is similar to the sun for the planets shine by reflected sunlight. Overlying the usual solar spectrum, however, are dark bands of some absorbing material, which bands become stronger and stronger as we proceed outwards from Jupiter to Saturn, to Uranus and finally to Neptune, in whose spectrum they are of exceedingly great intensity.

The origin of these bands has until recently been an enigma. They were shown not to be due to water vapour which absorbs considerable sunlight in our own atmosphere. Indeed, the low temperatures already suggested would preclude such an origin. At Mount Wilson and Lowell observatories much study has been given to the question and it is found that the atmospheres of Jupiter and Saturn are both rich in ammonia, a compound of hydrogen and nitrogen, and particularly in methane, a compound of hydrogen and carbon.

But while comparisons with laboratory spectra showed both these gases to be present in the atmospheres, yet it was not at first found possible to identify all the bands as due to these substances. It was felt that if the laboratory conditions could be made as similar as possible to those encountered in the planet's atmosphere, there would be more chance of settling the question as to whether these gases were in themselves sufficient to account for all the bands.

Now the atmospheres are extensive and so a great length of the gas to be tested must be available. The same condition will be met by using a shorter column of gas but increasing the pressure greatly. At the Lowell observatory they used two-inch high pressure steam tubing to contain the methane gas which was subjected to a pressure of 40 atmospheres. The light which passed through this tube had an equivalent path of about a mile at atmospheric pressure, and photographic records showed that twenty of the bands seen in the spectra of Jupiter and Saturn were likewise absorbed by this column of methane gas. In other words the unknown bands could be matched in almost every detail, simply by passing sunlight through this column of methane gas. There is hence no longer any doubt that the heavy absorption bands are due to methane, the principal constituent of natural gas.

While a few of the strongest bands were not actually reproduced, it was felt that if a longer column of gas had been available such would have been recorded. In such band spectra, however, there are certain mathematical relations, by which, when you know a few of the lines, you can predict all other possible ones. The test showed that bands should occur in the exact positions where they were recorded in the planetary spectra.

Experiments made with other possible hydrocarbons as the absorbing medium failed to suggest the presence of any of them in appreciable quantities. It appears, then, that methane is the major constituent of the atmospheres of these distant bodies, the quantity in the absorbing strata increasing markedly from Saturn to Neptune. Thus the riddle of the composition of the atmospheres of the major planets has at last been solved.

No. 80.—THE ATMOSPHERE OF THE EARTH

(March 19, 1935)

My last address dealt with the atmospheres of the outer planets, particularly Jupiter and Saturn, which we found to consist largely of methane, one of the principal constituents of natural gas.

In a former talk I referred incidentally to the earth's atmosphere.

I wish to enlarge upon it now in view of the interest in expeditions trying to reach the upper portion of our atmosphere, which is known as the stratosphere.

The composition of our atmosphere is as follows: Nitrogen 78%, Oxygen 21%, Argon 0.9%, with traces of Carbon Dioxide, Hydrogen, Neon, Helium, Krypton and Xenon. The air, of course, always contains more or less water vapour which may on warm days near large bodies of water reach as much as 5% by volume. It is paradoxical that the air is driest after a rain; during a spell of hot, dry weather it may contain so much water that the humidity, as we call it, becomes almost unbearable.

Until recent years little was known of the earth's atmosphere, other than its composition. From observations made on mountain tops and from balloons carrying observers it was assumed that the higher one ascended the colder the air became, but this has lately been disproved. It is true, however, for the region of air with which we are most familiar, the shell of air closest to the earth extending upwards to a height of possibly five to ten miles and known as the troposphere. In this region clouds form and storms originate. In it, as just stated, the temperature drops the higher we ascend until at its ceiling temperatures as low as –60° to –70°C. are attained. It is rather remarkable that the lowest temperature determined was not in high latitudes, but above the tropics, a temperature of –80°C. having been recorded at an altitude of ten miles above Java.

Naturally at first such observations were not made by observers from balloons but by automatic recording instruments which were sent aloft in what are known as registering balloons. These are small hydrogen filled balloons three or four feet in diameter, which when inflated and released rise to great heights before they burst. A tiny parachute brings the instrument safely to earth and many are recovered.

The height of the troposphere is not constant but varies with the latitude and to a certain extent with the season. There usually is a well-defined height where the temperature ceases falling and remains constant for the next mile or so. This layer is known as the tropopause, a very appropriate designation since the temperature pauses in its downward trend before starting upwards again. The region

immediately above the tropopause is known as the stratosphere and here we have the temperature actually rising with increasing height.

As to the height of the troposphere, (the layer nearest the earth), we may say that at the poles it extends upward 6 miles, at the equator it is 11 miles in height and at our latitude about 7 or 8 miles, a rather curious arrangement. The rotation of the earth probably plays a part in this "heaping up" of the atmosphere above the equatorial regions, and to an outside observer, on one of the other planets our equatorial diameter might appear perceptibly increased, though the increase due to this cause would be only 10 in 8000.

Before discussing the stratosphere let us state some facts about the troposphere. It is always turbulent even though such is not evident to the eye. This turbulence is brought about by the unequal heating of the earth's surface by the sun, not only because different parts of the earth's surface absorb heat differently but by reason of latitude and seasonal factors as well. This unequal heating, coupled with the deflective influence of the earth's rotation causes the ever-changing thing we call weather. With this we are not at the moment concerned, save to suggest that the air movements which we are conscious of are only a small part of the main air currents that flow silently overhead at altitudes of 5000 feet and upwards.

The atmosphere has weight. The barometer at sea level stands approximately at 30 inches; that is to say, a column of air reaching from the earth's surface to its extreme upper limit will balance a column of mercury 30 inches in height. This corresponds to a pressure of nearly 15 pounds per square inch to which we at sea level are always subjected. The pressure lowers about one inch for every 1000 feet in altitude which we rise, so that in the Rockies at elevations of 5000 feet we experience pressures 17% less than at sea level. When balloonists rise rapidly to great heights such as 20,000 to 30,000 feet and the outside pressure becomes much reduced, the normal blood pressure within the body is greater than that outside and bleeding occurs. It thus becomes necessary in flights into the stratosphere to seal oneself into a closed chamber wherein the pressure can be maintained somewhere near to that to which we are accustomed.

As has been stated, the stratosphere is the region of atmosphere

above the tropopause and troposphere. Its lowest level is, as suggested, about 6 miles at the poles, increasing to 11 miles at the equator. As far as it has been penetrated it shows that the temperature rises with altitude and it is suspected, though not proven, that if we could ascend in it high enough we would encounter temperatures similar to that on the earth's surface at the tropics.

Recently some notable attempts have been made to penetrate the stratosphere. In a sealed gondola in 1932 Picard reached a height of 10 miles. Settle and Fordney in 1933 attained 11½ miles and this was slightly bettered by three Russian balloonists about the same time. Last year the National Geographic expedition consisting of three experienced men, Kepner, Anderson and Stevens, attained a height of over 11 miles and would likely have gone three miles higher had not their balloon given way. They luckily escaped with their lives and were able to salvage some of their records, from which new knowledge has come regarding the stratosphere.

They consider that the problems of living and working efficiently in the stratosphere have been successfully solved. If such be the case, it may not be a far cry to the time when we shall be able to seal ourselves into a gondola and, choosing the proper level for a favourable air current, be transported rapidly to distant parts of the earth.

THE GREEN LINE OF THE AURORA

By J. F. HEARD

IN the year 1925 the late Prof. J. C. McLennan and Dr. G. M. Shrum, now of the University of British Columbia, discovered the identity of the famous and mysterious "green line of the aurora", the spectral line of wave-length 5577.35, in which is concentrated most of the light of the familiar northern lights. These two investigators showed that the green line was to be attributed to the oxygen atom. It was also proved in a series of experiments by McLennan and his colleagues that the emission of the green line by oxygen atoms required that those atoms, by some means or other, get into a particular energy state designated $^1S_0$, and known as one of the metastable states. Under ordinary conditions of excitation to luminosity, oxygen atoms do not populate this $^1S_0$ metastable state in sufficient numbers to cause emission of the green line, and this is the reason that the green line was, for such a long time, not associated with oxygen. The experiments of McLennan and others have shown that there are a number of ways in which the green line can be produced in the laboratory, that is, ways in which the $^1S_0$ metastable state can be populated. For example, low pressure helium, argon or nitrogen, containing traces of oxygen and excited to luminescence by an electric current, yield light which contains the green line. What particular mechanism in the upper atmosphere is effective in populating the $^1S_0$ metastable state with oxygen atoms and so producing the auroral green line? Several spectroscopists have tried to answer this question but none has given a completely satisfactory answer.

Prof. Joseph Kaplan, of the University of California, has for some years interested himself in this problem of the excitation of the aurora and now he has published a paper* which contains his answer to the riddle. Kaplan has attacked the problem in the most direct manner, namely, he has set out to produce the auroral

*The Excitation of the Auroral Green Line by Metastable Nitrogen Molecules, *Physical Review*, vol. 49, p. 67, 1936.

green line "in a laboratory experiment in such a way that both its appearance and mode of production fit in with observed and hypothetical facts about the upper atmosphere." He finds that if he passes a weak interrupted current through low-pressure nitrogen containing a trace of oxygen he produces the green line accompanied by those faint bands of the nitrogen molecule which accompany the green line in the spectrum of the aurora and of the night sky. He finds, moreover, good reason to believe that the green line is produced along with the *after-glow* of the nitrogen discharge, *i.e.*, that light which persists for a moment after the current has been interrupted; and, since this after-glow is known to be produced by molecules of nitrogen in a certain metastable state, he reasons that it is through collisions between these metastable nitrogen molecules and the oxygen atoms that the oxygen atoms are sent into the $^1S_0$ metastable state where they are in a position to emit the green line.

Professor Kaplan's experiments and conclusions will be of interest to those who have considered the puzzles of the upper atmosphere and the results of his further experiments in this same field will be eagerly awaited.

METEOR NEWS

Observations relating to meteors and meteorites are cordially invited.

THE CAROLINA BAYS AND THEIR SUPPOSED METEORIC ORIGIN.

During recent years meteor craters, singly and in groups, have been recognized as existing in several widely-separated regions of the earth's surface. It was natural that the announcement by Melton and Schriever, at the end of 1932, that the 3,000 elliptical "Bays" in the Carolinas were best explained by meteoric impact, should cause widespread interest. Since then their point of view has been considerably developed in articles in various periodicals and has been tentatively accepted by many scientists, including some astronomers.

In considering the formation of a large crater one important factor is commonly forgotten. This is, that any meteoric mass greater than a few yards in diameter will be very little retarded by the earth's atmosphere and, striking the ground with its cosmic velocity, must dissipate energy which, per unit of mass, is many times greater than the most powerful explosive known. This subject has been well treated by A. C. Gifford in the *New Zealand Journal of Science and Technology* for 1924 and 1930. His conclusions were reprinted in the JOURNAL of the R.A.S.C. for 1931, page 70. He shows that the explosive violence resulting from the rapid dissipation of the tremendous kinetic energy of a large meteoric impact will completely obliterate the original scar.

Returning now to a consideration of the "Carolina Bays", the writer desires to call attention to a most excellent article by Fletcher Watson, Jr., which appears in *Popular Astronomy* for January, 1936. In it Mr. Watson first points out the almost uniformly circular character of the definitely recognized meteor craters on the earth's surface. Single craters are located in Arizona and Texas, U.S.A., and crater groups at Henbury, Australia; Wabar, Arabia; Oesel, Esthonia; and in Tunguska, Central Siberia. (For completeness this list should include the Campo del Cielo craters in the Argentine and the crater recently excavated by H. H. Nininger near Haviland,

Kansas. The certainty of the meteoric origin of these last-named cases is just as great as for the craters in Esthonia and Siberia.) In the few cases where large meteor craters are definitely elliptical they are associated with circular craters and there is evidence to show that they are the remains of two overlapping circular craters which have suffered by erosion. Mr. Watson gives six reasons why the physical characteristics of the Carolina Bays cannot be reconciled with a meteoric origin. The Carolina Bays are all elliptical with an average ellipticity greater than 0.3 while known meteor craters are roughly circular. Since large meteorites may encounter the earth's surface at any angle from the horizontal to the vertical it is probable that the majority of these known craters were formed by meteorites striking at fairly large angles with the vertical and in fact there is good evidence to show that in two cases the meteorites made an angle of 45° or more with the vertical. Why then, should meteorites striking at an angle produce the elliptical Carolina Bays? From the theoretical standpoint also it is difficult to see how an unusually massive meteorite can reach the ground without developing a large explosive force which will be primarily non-directional and will produce an approximately circular crater. The Bays are much shallower in proportion to their mean diameters than are the existing examples of meteor craters. There has been no explanation of what has happened to the vast amount of material removed from the Bays, to account for which the low rims are entirely inadequate. The lower ellipticity of the smaller Bays has been considered to show evidence of atmospheric retardation, producing more nearly vertical paths for the smaller meteorites. If, however, the atmosphere has had any marked effect of this nature most of the smaller Bays would be found near one end of the region over which they are distributed and the larger ones near the other. This is not the case. Finally, the periodic meteor showers are the only examples of meteoric streams in space which we can study at close quarters and no known meteorite has a proved connection with any of these showers. Hence they seem to be composed of small meteors in the main and the earth's encounter with a group such as might have formed the Carolina Bays, while possible, is not very probable. Another point,

which Mr. Watson makes, is that the iron meteorites of the Appalachian Mountains region, which by some writers have been associated with the Carolina Bays, show no particular evidence of all being of the same type, show no distribution similar to the Bays, and give no evidence of being as old as the Bays.

The writer would here like to express himself as in complete agreement with Mr. Watson on the origin of the Carolina Bays. Since the reading of the first paper by Melton and Schriever in 1932 the almost uniform ellipticity of these objects has seemed to him an insuperable difficulty in a consideration of their meteoric origin. That a great meteor, moving with cosmic velocity, could create a marking over a mile in length and leave only a low sandbar as a crater rim seems unlikely. But if other geologic evidence of the meteor's impact had been left, would it not be as enduring as the sandbar? The absence, in the case of the Carolina Bays, of all reports of silica glass, lava bombs, or shale balls such as found in connection with other meteor craters also seems significant.

Prof. Wylie's suggestion (*P.A.*, vol. 41, p. 211, 1933) that the explosive action of impact might be continuous for a short time as the meteor plowed along or through the earth is conjectural and is not subject to even qualitative proof. In addition, one would expect a crater formed in this way to show a marked asymmetry of form quite different to the comparatively regular outlines of the Bays.

Prof. G. R. MacCarthy is reported in *Science* for Jan. 17, 1936, as ascribing the formation of the Bays to the air blast accompanying the meteorites. He thus explains the slight deviation of the Bays from uniform orientation. For meteorites large enough to form the Bays the air blast would represent but a small portion of the energy to be dissipated and all the previously stated objections to the meteoric hypothesis remain.

When difficulties are encountered in one field of scientific investigation there is often a tendency to relegate the explanation of these difficulties to another field where the objections to the explanation are not quite so clearly seen. The writer, being no geologist, would hesitate to express an opinion on the relative merits of the other suggested origins of the Carolina Bays. He is convinced, however, of the inadequacy of the theory of meteoric impact.

Meteor Photography in Texas

Word has been received from Mr. O. E. Monnig that the Texas Observers of Ft. Worth enjoyed clear weather during the early morning hours of Jan. 3rd, 1936. Two meteor spectrographs and one direct camera were used in an attempt to photograph the Quadrantids. Total exposure times were 4.0 hrs. with the spectrographs and 2.0 hrs. with the direct cameras. A slow sporadic flickering meteor of magnitude 0 to −1 was photographed with one spectrograph and the direct camera. Unfortunately the meteor crossed the field of the spectrograph nearly parallel to the direction of the dispersion so that the spectrum shows little detail.

Nebulous Meteors

In reference to the note on nebulous meteors which appeared in these columns a few months ago, Mr. Frank M. Preucil, of Joliet, Ill., writes that he has noted three such meteors out of 71 telescopic meteors observed during the last two years. All had appreciable diameters and were hazy. One, of the 11th magnitude, was observed in a 16-inch telescope while using a power of 135. The other two were of 7th and 9th magnitude respectively and were observed while using a power of 14 on a 6-inch telescope, the field being 3.5 degrees in diameter. These nebulous meteors form a very interesting problem and the writer would be glad to receive reports of any others which may be observed, either through the telescope or with the naked eye.

P. M. M.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Prophets of Science

The scene is at Homs in Syria, the time is March, 1905. The speakers are Gertrude Bell, the famous traveller, archaeologist and administrator, and the Kadi of the town.

I asked him next whether he had any acquaintance with the Beha'is. He answered:

"As for the Beha'is and others like them, your Excellency knows that the Prophet (may God give him peace!) said that there were seventy-two false creeds and but one true, and I can tell you that of the seventy-two there are certainly fifty in our country."

I replied that it appertained to prophets alone to distinguish the true from the false, and that we in Europe, where there were none to help us, found it a difficult task.

"In Europe," said the Kadi, "I have heard that the men of science are your prophets."

"And they make answer that they know nothing," I observed. "Their eyes have explored the stars, yet they cannot tell us the meaning of the word infinity."

"If you speak of the infinite sky," remarked the Kadi, "we know that it is occupied by seven heavens."

"And what beyond the seventh heaven?"

"Does not your Excellency know that the number one is the beginning of all things?" said he. "When you have told me what comes before the number one, I will tell you what lies beyond the seventh heaven."—*Arabia—the Desert and the Sown* by Gertrude Lowthian Bell.

Royalty and the Time

It is stated that King Edward VII at one time was late for an appointment—a thing a king is never supposed to be—and that he forthwith ordered the clocks of Sandringham House to be put forward half an hour. His successor George V, out of respect for his father's memory, allowed them to remain so, but now the new king, Edward VIII, has had them set right again.

It may be recalled that in 1917 a resolution was proposed in the Canadian House of Commons that "daylight" time be introduced in Canada, but it was laughed out of the house. Next year, how-

ever, daylight time came into use in Canada and the clock in the Commons chamber had to be changed. We are all slaves of the clock!

THE LATE R. A. GRAY

Elsewhere in this issue appears a tribute to the late R. A. Gray, by Mr. J. H. Horning, who for over ten years served under him as a teacher in the large educational institution of which Mr. Gray was principal, and who also acted with Mr. Gray on the Council of the Royal Astronomical Society of Canada.

Perhaps I may be permitted to add a personal note. Having graduated in the same course in the University, he six years earlier than I, we were naturally interested in each other. I do not recall when I became acquainted with him,—certainly more than thirty years ago, at which time he had reached some prominence among secondary school teachers. He was a man of the highest principles, an able mathematicain, a clear thinker, a wise administrator. Naturally he was able to secure the positions he sought for, until at last he obtained one of the very highest in the province. This he filled with distinction for twenty-one years,—until his retirement at the age limit. The influence of his just and manly nature upon the successive classes of youths which passed under his guiding hand will remain with them throughout their lives.

C. A. C.

MEETINGS OF THE SOCIETY

AT VANCOUVER

May 14, 1935.—The meeting was held at 8.15 p.m. in the Science Building of the University of B.C., Dr. William Ure presiding in the absence of the president, Prof. W. H. Gage.

Previous to the meeting the Society's annual dinner was held at 6.30 p.m. in Union College. This pleasing occasion was enjoyed by seventeen members of the Society. Dr. Ure reminded the members of the annual visit to Victoria and the secretary was requested to write to Victoria Centre requesting a suitable date for this visit.

The speakers of the evening, Mr. Paul Sykes, subject, "Stars of the Month"; Mrs. Laura Anderson, "The Moon"; Mr. Seto More, "The Planets and Asteroids"; Mr. J. W. Moore, "The Sun".

Mr. Paul Sykes referred to planetary detail and observational advantages during the next few weeks. His remarks were specially encouraging and useful to the amateur astronomer.

Mrs. Laura Anderson began with recollections of some pleasant childhood memories. At an early age her impression of the moon was that of an escorting celestial fairy. She dwelt upon such features as the moon's distance, diameter, rotation, gravity, absence of weathering properties, of its shadows, craters, prevalence of meteorites owing to absence of atmosphere. Mrs. Anderson added to her very interesting talk by showing some excellent slides, suitably explained.

Mr. J. W. Moore in speaking of the sun enlarged upon many of its features, such as its galactic position being one-third from the centre of our galaxy, its diameter and gaseous exterior. He described it as a sphere 330,000 times the mass of the earth, and its heat being caused without combustion. He gave its diameter as 865,000 miles, and its distance from the earth as 93 million miles. The rice-grain markings and sun-spots and their 11-year cycle were clearly explained, and its rotation was given as approximately 25 days. He stated that terrestial magnetic disturbances and auroral displays were more prevalent during the presence of sun-spots. A definition was given of the solar corona seen during eclipse, of sun prominences and the chromosphere, special mention being made of the absence of sun-spots near the poles. Mr. Moore rounded off his fine talk by showing some very suitable slides, with suitable explanations.

Mr. Seto More referred to the absence of an atmosphere on Mercury and to the fact that its rotation and revolution periods were the same, each being 88 days. This renders that face turned to the sun very hot and that away from the sun very cold. Venus has a dense atmosphere, a revolution period of 225 days and an undetermined rotation period. Mars was described as a planet, distance

142 million miles from the sun, having a surface of comparatively clear definition, with "canal" markings and polar caps showing seasonal changes. He gave a very interesting account of the asteroids, 1,100 of which have been catalogued. Jupiter was next described as a planet 483 million miles from the sun, with a period of revolution 11.88 years and accompanied by nine satellites, four of which were discovered by Galileo. As an interesting feature he stated that the Chinese calendar was governed by observations of Jupiter. The properties, mass, diameter and period of rotation of Saturn and Uranus were next dwelt upon. A brief history of Pluto and its discoverer, Percival Lowell, brought to a close his interesting talk on planets, after which some splendid slides were shown and explained. Many interesting questions by members and visitors were asked and answered.

The subject of summer meetings was brought up and an announcement made that two would be held in July and one in August.

C. A. McDONALD, *Secretary*.

AT VICTORIA

November 20, 1935.—The meeting was held in the Y.W.C.A. parlors, commencing at 8 p.m., Lieut.-Comdr. Tingley, presiding.

Mr. Robert Peters gave a short description of current phenomena, and also a brief sketch of the discoveries of Halley, with some references to the work of Newton.

Dr. Andrew McKellar was called upon for his address on The Spectroscope and its Uses. The speaker described the nature of light and light-waves as disturbances in an electromagnetic field. All colour in nature was due to differences in the wave-lengths of the components of white light, varying from violet, the shortest, to red, the longest, in the visible spectrum. The history of the spectroscope was traced back to Newton, and in its later developments to Fraunhofer. By diagrams the spectroscope was shown to be a simple instrument, consisting of the collimator, the prism, and the view telescope. In the spectrograph a camera is used instead of the telescope.

The practical use of the spectroscope and spectrograph in conjunction with the astronomical telescope was shown to be very valuable. The composition, heat, size, distance and radial velocities of stars were determined by means of spectrograms. Binary systems and doubles were also disclosed by spectroscopic means. Dr. McKellar had set up an excited neon tube and spectroscope with which to view it. Many lantern slides were used to illustrate the lecture.

After a short discussion, Mr. Peters proposed a vote of thanks to the speaker for his excellent address.

GORDON SHAW, *Secretary*.

WANTED—An amateur in Saskatchewan wishes a 2- or 3-inch refractor. Send particulars to The Editor.

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